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Avoidance and Escape Responses of the Gastropod *Nucella emarginata* (Deshayes, 1839) to the Predatory Seastar *Pisaster ochraceus* (Brandt, 1835)

by

MELISSA L. MILLER

Bodega Marine Laboratory, Bodega Bay, California 94923, U.S.A. and
University of California, San Diego, La Jolla, California 92093, U.S.A.[1]

Abstract. The gastropod *Nucella emarginata* (Deshayes, 1839) exhibits both avoidance and escape responses to the predatory seastar *Pisaster ochraceus* (Brandt, 1835). When exposed to water "scented" by *P. ochraceus, N. emarginata* demonstrated a strong avoidance response that was absent when exposed to normal (control) seawater. *Nucella emarginata* also responded rapidly to the touch of a tube foot from *P. ochraceus* by changing direction and increasing mobility. Little or no response was elicited by the touch of a glass rod.

INTRODUCTION

MANY GASTROPOD mollusks exhibit defensive behaviors in response to predatory animals. These have been considered to be of two types: avoidance and escape behaviors (PHILLIPS, 1977). Avoidance behavior is exhibited when a prey species, responding to substances that have diffused from a predator through the water, reacts to the presence of the still distant predator (FEDER & ARVIDSSON, 1967; MACKIE, 1970). Escape behavior is a response to actual contact with the predator. There are many documented examples in the literature of escape responses and chemically mediated avoidance responses by marine gastropods to predatory asteroids, crabs, and gastropods (BULLOCK, 1953; EDWARDS, 1969; FEDER, 1963, 1967; GELLER, 1982; GONOR, 1965; MACKIE, 1970; MARGOLIN, 1964; MENGE, 1972; PHILLIPS, 1975, 1976, 1977, 1978).

Nucella emarginata (Deshayes, 1839) and *Pisaster ochraceus* (Brandt, 1835) are two species that overlap both in spatial distribution and dietary composition. They are also linked in prey-predator interactions, as *N. emarginata* is one of the species preyed upon by *P. ochraceus* (BERTNESS, 1977; FEDER, 1959). *Nucella emarginata* is found on rocky shores ranging from Alaska to Mexico (RICKETTS & CALVIN, 1968) and has been previously shown to demonstrate a weak defensive response to the predatory seastar *Leptasterias hexactis* (MENGE, 1972).

The purpose of the present study is to determine if *Nucella emarginata* exhibits avoidance and escape responses to the predatory seastar *Pisaster ochraceus*. (Henceforth *Nucella emarginata* and *Pisaster ochraceus* will be referred to by their generic names only.)

MATERIALS AND METHODS

Study Sites

Specimens of *Nucella* were collected from Dillon Beach and Doran Rocks, two locations near Bodega Bay, Sonoma County, California. Both sites are boulder-strewn beaches supporting abundant populations of this gastropod.

Experimental Methods

Snails from both sites were maintained at the nearby Bodega Marine Laboratory (BML) in running seawater in a partitioned aquarium. A separate aquarium housed a seastar, collected from the coast adjacent to the BML.

The apparatus for testing both escape and avoidance responses consisted of four open-top boxes constructed of 0.32-cm thick plexiglas with dimensions 30.5 × 30.5 × 2.54 cm. A grid of 28 × 28 cm in 1-cm gradations was drawn on the base. Gradations were identified along one side by numbers and along the perpendicular side by letters of the alphabet in order to record the displacement of the snail without disturbance.

[1] Present address: 6086 48th Street, San Diego, California 92120, U.S.A.

Table 1

Avoidance response of *Nucella emarginata* from two sites, Dillon Beach and Doran Rocks, and the combined results from both locations. Fifty snails were used in each trial. The test criteria for a positive response were shell lifting behavior, changing direction, or a combination of both behaviors. A response was scored as negative if there was no apparent change in activity. χ^2 values resulted from comparing the control with the seastar run by means of a 2 × 2 contingency table corrected for continuity. ** = $P < 0.001$.

Site	Positive responses	Negative responses	χ^2
Dillon Beach			
Control	1	49	
Pisaster-scented water	49	1	88.36**
Doran Rocks			
Control	5	45	
Pisaster-scented water	47	3	67.35**
Dillon Beach and Doran Rocks			
Control	6	94	
Pisaster-scented water	96	4	158.48**

Table 2

Escape response of *Nucella emarginata* from two sites, Dillon Beach and Doran Rocks, and the combined results from both beaches. Fifty snails were used in each trial, and the test criteria were as in Table 1. χ^2 values resulted from a comparison of control with seastar trial data by means of a 2 × 2 contingency table corrected for continuity. ** = $P < 0.001$.

Site	Positive responses	Negative responses	χ^2
Dillon Beach			
Control	5	45	
Pisaster tube foot touch	42	8	52.02**
Doran Rocks			
Control	4	46	
Pisaster tube foot touch	44	6	60.93**
Dillon Beach and Doran Rocks			
Control	9	91	
Pisaster tube foot touch	86	14	115.80**

In the avoidance response test procedure, the seastar was weighed and placed in a 4-L beaker containing 3 L of seawater. After 2 h water from the beaker containing the seastar was poured into a 250-mL beaker for use in the experiments. The plexiglas boxes were filled to a depth of 1 cm with fresh seawater. Snails were measured with calipers (apex to end of siphonal canal), and placed, one per box, at the center of the grid. Once the snail's foot was extended, 1 mL of fresh seawater or 1 mL of scented water was allowed to flow freely from a pipette 2 cm from the anterior end of the snail. Responses were closely observed and recorded for 5 min. The position of the snail, based upon the location of the apex of the shell, was recorded at the end of 5, 10, and 15 min. Fifty snails were tested from each site. Control and experimental trials were conducted on consecutive days.

In the escape response test procedure, the plexiglas boxes were each filled to a depth of 1 cm with fresh seawater. Snails were measured and placed, one per box, at the center of the grid. Once the foot was extended, the snail was touched anteriorly either with the tip of a glass pipette or a tube foot that had been removed from a seastar and was held with forceps. Responses were closely observed and recorded for 5 min. Displacement of the snails was recorded at the end of 5, 10, and 15 min. Fifty snails were tested from each site. Control and experimental trials were conducted on consecutive days.

Between each trial the boxes were rinsed in running seawater. The pipette was also rinsed between each trial in the escape response procedure. A tube foot was used four times before being discarded and replaced. In all trials, a positive response was defined as a change in behavior from that observed prior to the stimulus.

RESULTS

Nucella responded to the scent of *Pisaster* (Table 1). A total of 96 of 100 snails responded to the *Pisaster*-scented water, while only 6 of 100 responded to fresh seawater, a highly significant difference ($\chi^2 = 158.5$, $P < 0.001$). The behavior exhibited by *Nucella* when exposed to the *Pisaster*-scented water was remarkably different from activity prior to exposure. Some snails (2.1%) were observed only to lift their shells repeatedly and extend upward the body mass between the head and foot. They appeared to be rocking back and forth. Others moved in circles (21.9%), while many others combined both responses (76.0%).

Nucella exhibited an escape response when contacted by the tube foot of *Pisaster* (Table 2). A total of 86 of 100 snails responded to the tube foot touch compared to only 9 of 100 responding to the touch of the tip of a glass pipette. Trials involving tube foot touch were significantly different from control trials ($\chi^2 = 115.8$, $P < 0.001$). The escape response by *Nucella* was similar to the avoidance response, but it was not as pronounced. Snails were observed to lift up only initially, and then make 180° change of direction from the point of stimulus. Snails were observed to lift up (2.3%), change direction (64.0%), and to change direction and lift up (33.7%).

DISCUSSION

The present study confirms that the gastropod *Nucella emarginata* does exhibit both avoidance and escape re-

sponses to the predatory seastar *Pisaster ochraceus*. The primary response of the snail was to change direction and increase its activity. It must be kept in mind, however, that laboratory studies, such as the test procedure used here for avoidance responses, are subject to the criticism that laboratory conditions do not duplicate those normally found in the natural habitat. For example, high concentration of seastar scent, minimal water disturbance, and smooth substrate are not naturally found in the intertidal zone. Assuming that the behaviors elicited in the laboratory also occur in the field, they would be advantageous to an organism such as *Nucella* whose habitat overlaps that of a predator, in this case, *Pisaster*.

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